spotlights

Organic Light

About 15 percent of the average American household's electricity goes to lighting—and existing lighting technologies are notoriously inefficient. Even today's green-tech compact fluorescent bulbs and LED lamps convert only 8–14 percent of the electricity they consume into light. Nonetheless, that's still many times better than incandescent bulbs, which are only 2–3 percent efficient. According to the U.S. Department of Energy, rapid adoption of existing LED lighting over the next 20 years could save the country $265 billion and eliminate the need for 40 new power plants. Better yet, in theory, future LED lamps could operate at a staggering 40-percent efficiency or slightly more, blowing away everything that exists today.

Los Alamos materials scientist Sergei Tretiak, working with colleagues at the University of Utah and Nanjing University in China, recently made important headway toward that tantalizing 40 percent. The team experiments with organic LEDs, or OLEDs, made from organic-polymer semiconductors instead of traditional semiconductors like silicon. They have a flexible, plastic appearance and are currently used in computer, smartphone, and high-end television displays. In these applications, red, green, and blue fluorescing OLEDs combine to make each pixel. The same can be done to make white light for OLED lamps (as is currently done for LED lamps), but this approach is prohibitively expensive. Instead, the objective for OLED lighting, if it is to reach that approximately 40-percent theoretical limit, would entail individual white pixels doubling up on output by combining fluorescence with phosphorescence.

"Phosphorescence normally won't happen," Tretiak says, "unless you provide certain metals that enable crossings between fluorescing and phosphorescing states." He and his collaborators selected atoms of platinum and inserted them at particular intervals along the chainlike OLED polymer molecules. When inserted at every chain link, the polymer produced violet fluorescence and yellow phosphorescence; at every third chain link, it produced blue fluorescence and orange phosphorescence. Both mixtures appeared whitish, and the team demonstrated that truly white light should be possible after a little tinkering with more complex platinum spacing, to adjust the colors and their relative intensities.

Does that mean the OLED-lighting revolution is already upon us? "Not just yet," admits Tretiak. The team's experiments used an additional light source to deliver energy to the polymers, but a true OLED would supply the energy with electricity instead. "So there's another step to go," says Tretiak. "But producing multiple colors from a single polymer gets us much closer." LDRD

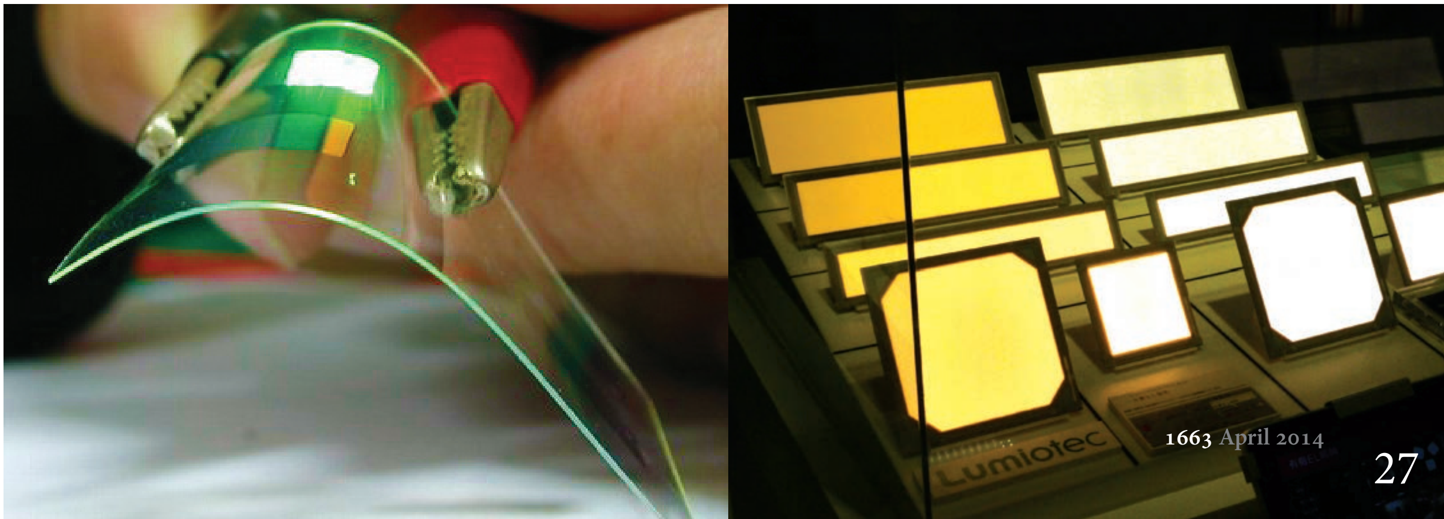
—Craig Tyler

Brighter Future for Cancer Detection

What do high-speed communication, advanced microscopy, high-tech security systems, and noninvasive cancer detection have in common? They are all made possible by fiber optics. Los Alamos researcher Judith Mourant is a light scattering expert using fiber optics to pioneer a new method to detect cervical cancer. Cervical cancer is still a common cancer for American women, despite an enormous decrease in incidence since the implementation of regular screening in the 1950s. After initial screening via the Papanicolaou test (a.k.a. Pap smear), abnormal or suspect findings are subjected to more sensitive diagnostic procedures, primarily colposcopy (illuminated magnification) and biopsy (tissue sampling). Biopsies are small portions of tissue and their removal (typically by scalpel or laser) can cause pain, infection, or other complications. Combine this with the stress of waiting for results, and some patients wind up avoiding the procedure until it may be too late. Furthermore, biopsies can only sample a small portion of the tissue. To improve this, Mourant and her team developed a noninvasive fiber-optic method that can improve the process of choosing when and where to biopsy that could eventually decrease both the cost of detection and stress to patients.

Mourant, along with former Los Alamos cell biologist James Freyer, previously showed that cancerous cells scatter light differently than noncancerous cells. When you hold a flashlight against your palm in a dark room, your hand will glow red. The red color is because your tissue absorbs the other colors of light, especially blue and green, while the red light, reflected off your blood cells, passes through. But it doesn't go straight through the tissue of your hand—it is scattered, or bounced around, by microscopic structures it encounters along the way. When light bounces off of structures in tissue, the change in intensity of the scattered light can be quantified and used to infer information about the physical properties and structure of the tissue.

After proving her method in laboratory-cultured cells, Mourant and her colleagues



A flexible OLED device (left) and prototype OLED lighting panels

CREDIT: meharris (left) and STRONGlk7/Wikimedia Commons packaged it into a safe and compact fiber-optic probe-based system that can be used during routine patient examination. Clinical trials performed in collaboration with researchers at the University of New Mexico Health Science Center and the Albert Einstein College of Medicine in New York compared the fiber-optic system against traditional colposcopy. Initial tests showed that the optical system has similar accuracy for the detection of precancerous lesions to that of well-trained and experienced colposcopists.

Presently, Mourant and Los Alamos technologists Oana Marina and Claire Sanders are trying to determine what specific molecular changes within the cell are responsible for the differences in light scattering, and they are looking at the potentially helpful effect of acetic acid. Topical application of acetic acid (the main component of vinegar) often causes cancerous and precancerous cells to visibly whiten and is regularly used during colposcopy. The problem with the acetowhitening-colposcopy system is that it relies on the human eye (the eye of whichever clinician is performing the exam), which permits neither quantification nor standardization. The whitened appearance is actually an increase in the amount of light reflecting from the tissue's surface, prompting Mourant to speculate that the molecular mechanism responsible for acetowhitening may also be involved in the light scattering differences exploited by her optical diagnostic system. If they can determine which cellular elements are scattering the most light, and whether these are the elements that are altered during cancer, they may be able to apply their analysis to other types of tissue and their corresponding cancers.

Determining properties of tissue by measuring the intensity of light that has passed through it is difficult, because it is hard to know where the light went without already knowing the detailed structure of the tissue. One approach to this problem is to simulate light transport through tissues with slightly different, predefined properties. To do this, Mourant has teamed up with Jerome Spanier and his team of mathematical modelers at the University of California at Irvine to develop computational methods to simulate light passing through different types of tissues. By bringing together cellular systems, optical systems, mathematical modeling, and high-performance computing, this technology will improve both the clinical experience and the accuracy of diagnosis.

Moving forward, Mourant sees this work being relevant to many other questions in cancer biology. "Using fiber optics to look at the insides of people is not new to medicine. But we are not just looking, we are diagnosing. And that is new and very exciting," she says. In fact, the diagnostic power of fiber optics is also being investigated by other research groups studying colon and esophogeal cancers, which frequently reach late-stage disease before diagnosis, have high mortality rates, and cost billions annually to treat. Indeed, just as high-speed communication and other modern conveniences have benefitted from fiber optics, so too may certain essentials of health and longevity.

—*Eleanor Hutterer*

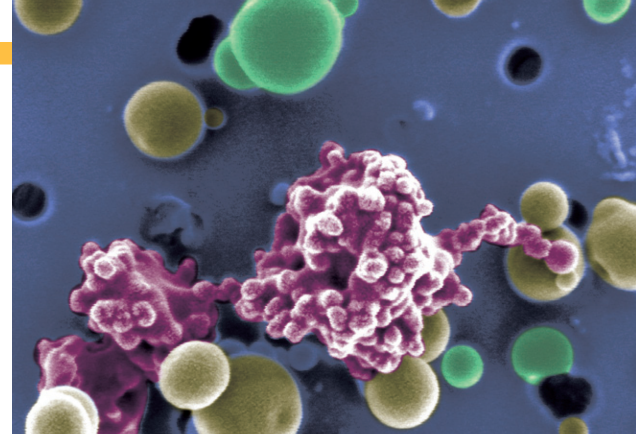
The probe used during a clinical exam for fiber-optic detection of cervical cancer is about 3 millimeters in diameter.

Warming by Wildfire?

Here's the thing about predicting the climate: it's all based on models. Models are built with the pieces you have, and you need the right pieces to get the right prediction. According to Los Alamos climate scientist and emissions expert Manvendra Dubey, the models currently being used to simulate and predict climate change may not have all the right pieces when it comes to wildfires.

When the record-breaking Las Conchas megafire came to Los Alamos's doorstep in June of 2011, Dubey saw an opportunity for discovery. The town had been evacuated at the peak of the threat, but once the fire was reduced to a smolder and the evacuation order was lifted, Dubey and his team hurried to deploy aerosol emissions sensors. They wanted to know what kind of carbon particles were in the air after such a large, hot fire. The size and shape of the collected particles were examined by electron microscopy, and the results were startling.

The majority of collected particles were amorphous, spherical carbon particles called tarballs. These can have either a warming or cooling effect on climate, depending on whether they absorb or scatter sunlight, but are not normally taken into account in climate models because they aren't considered significant. The team expected to see some tarballs in their analysis, but they saw a lot— in fact, the tarballs were the dominant type of particle. Another surprise was that there were two kinds of tarballs—dark and bright—visible in the electron microscopy images. The team, which included Claudio Mazzoleni of Michigan Technological University (formerly a Los Alamos Director's postdoctoral fellow mentored by Dubey), found that dark tarballs, which comprise about a third of the tarballs examined, are more highly oxidized than bright tarballs. Highly oxidized organics like these are more efficient than less-oxidized organics in taking up water to become cloud drops—the tiny droplets of water that largely make up a cloud. By increasing the number, size and concentration of these drops within a cloud, the presence of dark tarballs, counterintuitively, makes the cloud reflect more sunlight, resulting in a cooling effect.



False-color scanning electron micrograph showing aerosol particulates collected from Los Alamos after the Las Conchas megafire in 2011. Three types of carbon particles are shown: climate-cooling dark tarballs (green), climate-warming bright tarballs (soft yellow), and an aggregated clump of organic-coated soot particles (pink).

Dubey also found another surprise in the Las Conchas fire emissions analysis, this one involving soot particles—small spherical particles of black carbon that aggregate together in chain-like clumps. Most of the soot particles examined were coated with other organic compounds from the fire—compounds that focus sunlight, resulting in a warming effect. This means that soot particles, which are treated as bare in most climate models, are being modeled incorrectly because the organic coating alters their optical (light absorbing or reflecting) and physical-chemical (aerosol-cloud interaction) properties. At the time, the Las Conchas fire was the largest in New Mexico history (156,000 acres); however, the following year the Whitewater-Baldy Complex fire became the new record holder (289,000 acres), and Dubey's team confirmed their dark tarball and coated-soot findings from that fire as well.

Emissions from burning biomass include both light-absorbing particles (soot and black carbon) as climate warmers and light-scattering particles (organic carbon and smoke) as climate coolers. Current climate models typically indicate small wildfire contributions to climate because they assume that the warming particles and cooling particles offset each other's effect. Dubey's work has shown that not only is the composition of carbon-based aerosols more complex than previously realized, but the relative warming and cooling contributions of each of these types of particles do not necessarily cancel: warming can win.

Dubey concludes that global climate models, which only include organic aerosols (cooling) and bare soot (warming), ought to include both kinds of tarballs (warming and cooling) as well as soot coated with organics (more warming than bare soot). Punctuating this recommendation is the rising incidence of record-breaking wildfires in New Mexico, the American Southwest, and the rest of the world. It is a ferocious feedback loop: as the climate warms from greenhouse gas emissions, fires will be larger, hotter, and more frequent and will emit an abundance of tarballs and soot. The next challenge is to determine just how much warming is actually canceled by cooling. According to Dubey, it may be less than we thought. LDRD

—Eleanor Hutterer

Supernova for National Security

What Los Alamos astrophysicist Chris Fryer realized as he looked at the latest NuSTAR images of Cassiopeia A (Cas A) was that, in a curious way, the country had just been handed a windfall. Cas A is a supernova remnant—the stellar debris that remains after the core of a supermassive star implodes and gives birth to a neutron star, but then explodes and blows the rest of the star apart. NuSTAR is NASA's high-energy x-ray telescope that had been mapping the location of titanium nuclei in the still-expanding debris field, now some 10 light-years across. The windfall, however, begins with NuStar's older brother spacecraft, the Chandra X-ray Observatory.

"The Cas A debris field is turbulent," says Fryer, "and over the course of several years, Chandra captured beautiful images of turbulent mixing. We hoped we could use the images to test our computer codes, but that wasn't possible at the time."

Every computer simulation of a supernova includes code that accounts for turbulence in the core and body of the star. But is that code correct, and are the physics models that describe the turbulence correct or even adequate? The only way to be sure is to simulate the system and compare its output turbulence with the signature swirls, whorls, and plumes displayed by the real system. However, the swirls and whorls seen in Cas A today are in part due the shape of the star's core when it blew up. That shape was unknown, and thus there was too much uncertainty in the simulation to deduce if it reflected reality or not.

Interestingly, turbulence also shows up in another system that first implodes then explodes—the plutonium core of a nuclear weapon. Like the astrophysicists, weapons scientists need to validate and verify their computer codes that model weapons performance. Unfortunately, it is extraordinarily difficult to obtain data that could be used to test the weapons code. Fryer had proposed using the Cas A data.

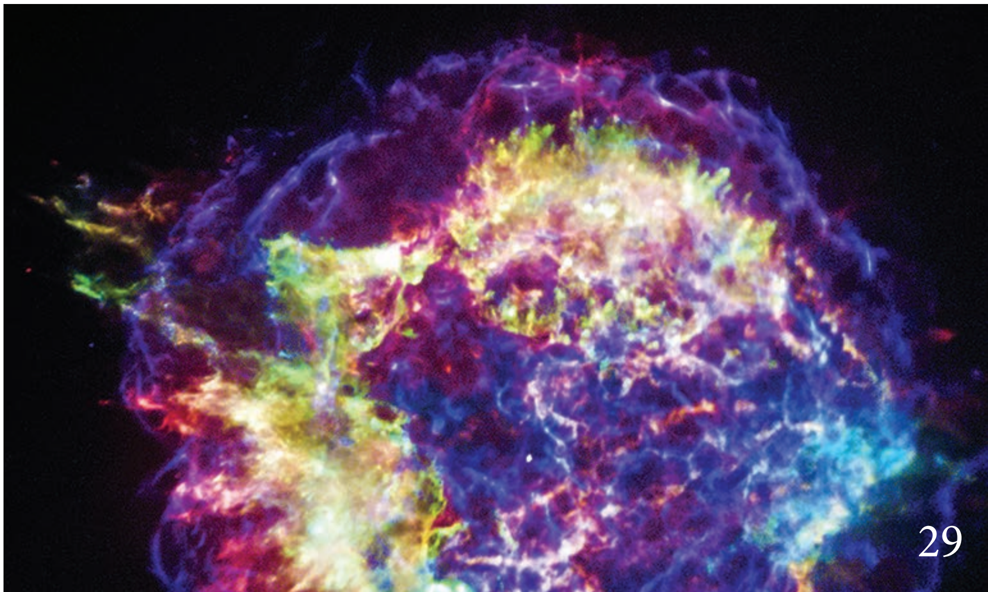
Wait a minute. Why should the turbulence within a supernova remnant 10 light-years across have anything to do with the turbulence of a detonated nuclear device? The answer is that the underlying physics is the same—and the physics governs the type of turbulence that emerges within each system.

"We've been able to learn more about how to model a nuclear weapon by modeling supernovae," says Fryer.

Supernovae are perhaps the best examples of how basic science, the cornerstone of the U.S. and the world's technological powerhouses, can support the weapons program. But it's not the only example. In many specialized areas of science, where the expertise has traditionally resided behind the security fence, the much larger peloton of academic and private-sector scientists has closed the gap in basic knowledge, and as Fryer sees it, has a lot to offer the secretive and traditionally self-contained world of nuclear weapons.

Fryer has ties to both the academic and weapons communities. As a member of NuSTAR's science team, he's privy to the telescope's data. The titanium nuclei that were being mapped are only created in the core of a massive star and thus serve as markers for core material. What caught his eye was that the nuclei were distributed in a way that was entirely consistent with the latest models of core collapse and explosion. That meant that astrophysicists had a handle on the shape of the core that created Cas A and could estimate the uncertainties in reproducing the turbulence observed by Chandra. And that weapons scientists could to do similar tests with their codes using the Chandra data—for free. LDRD

—Jay Schecker



A composite image of the supernova remnant Cassiopeia A, combining low-energy (red), medium-energy (green), and high-energy (blue) x-ray images taken by the Chandra X-ray Observatory. The tiny bright dot in the center is believed to harbor a neutron star.

CREDIT: NASA/CXC/SAO